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Water and Nutrient Research: In-field and Offsite Strategies—2005 Annual Report

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Abstract

Much of Iowa is characterized by relatively flat, poorly-drained soils which, with extensive artificial subsurface drainage, have became some of the most valuable, productive lands in the State. In 2002, the average land value for the 22-county area making up most of the Des Moines Lobe was $2,436 an acre, and 80.5% of that area was in row-crops (42.9% in corn and 37.6% soybeans). However, this drained land has also become a source of significant NO3 loss because of the changes in land-use and hydrology brought about by tile drainage. While surface runoff is decreased with subsurface drainage (resulting in decreased losses of sediment, ammonium-nitrogen, phosphorus, pesticides and micro-organisms), subsurface flow and leaching losses of NO3 are increased. This is due mostly to an increase in volume and the "short-circuiting" of subsurface flow, but also in part to the increased aeration of organic-rich soils with potentially increased mineralization and formation of NO3 (and less denitrification) in the soil profile.

The problem of excess nutrient loads can probably be ameliorated by a combination of in field and off site practices, but the limitations and appropriateness of alternative practices must be understood and outcomes must be measurable. Promising in field practices include nutrient management, drainage management, and alternative cropping systems. Nitrate-removal wetlands are a proven edge-of-field practice for reducing nitrate loads to downstream water bodies and are a particularly promising approach in tile drained landscapes. Strategies are needed that can achieve measurable and predictable reductions in the export of nutrients from tile drained landscapes. The principal objectives of this project are (1) to evaluate the performance of nutrient management, drainage management, and alternative cropping systems with respect to profitability and export of water and nutrients (nitrate-nitrogen and total phosphorus) from tile drained systems and (2) to evaluate the performance of nitrate-removal wetlands in reducing nitrate export from tile drained systems.

This annual report describes activities related to objectives 1 and 2 along with outreach activities that were directly related to this project. Results for crop year 2005 are described.

Disciplines

Agriculture | Bioresource and Agricultural Engineering

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Annual Report for Crop Year 2005
(January 1, 2005 – December 31, 2005)

Water and Nutrient Research: In-field and Offsite Strategies

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Iowa Department of Agriculture and
Land Stewardship

Submitted by:
Department of Agricultural and Biosystems Engineering
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Water and Nutrient Research: In-field and Offsite Strategies

Much of Iowa is characterized by relatively flat, poorly-drained soils which, with extensive artificial subsurface drainage, have became some of the most valuable, productive lands in the State. In 2002, the average land value for the 22-county area making up most of the Des Moines Lobe was $2,436 an acre, and 80.5% of that area was in row-crops (42.9% in corn and 37.6% soybeans). However, this drained land has also become a source of significant NO_3 loss because of the changes in land-use and hydrology brought about by tile drainage. While surface runoff is decreased with subsurface drainage (resulting in decreased losses of sediment, ammonium-nitrogen, phosphorus, pesticides and micro-organisms), subsurface flow and leaching losses of NO_3 are increased. This is due mostly to an increase in volume and the "short-circuiting" of subsurface flow, but also in part to the increased aeration of organic-rich soils with potentially increased mineralization and formation of NO_3 (and less denitrification) in the soil profile.

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Gilmore City Project Site

Treatments

The specific treatments investigated at the Gilmore City Research Facility are listed in Table 1. All treatments except the harvestable perennials (Treatment 18) and living cover (Treatment 17) would consist of eight plots with four in soybeans and four in corn each year. The harvestable perennials and living cover each have four plots. The harvestable perennials and living cover were investigated during the winter of 2004 and planted in spring 2005 after discussion with the investigators and IDALS personnel.

Table 1. Treatments at the Gilmore City Research Facility for Crop Years 2005-2009.

Treatment Number*	Treatment	Nitrogen Application Time	Nitrogen Application Rate (lb/acre)
1,2	Conventional tillage	Fall	75
3,4	Conventional tillage	Fall	125
5,6	Conventional tillage	Spring (early season sidedress)	75
7,8	Conventional tillage	Spring (early season sidedress)	125
9,10	Conventional tillage	Spring (early season sidedress)	150
11,12	Strip tillage	Spring (early season sidedress)	125
13,14	Cover crops after harvest	Spring (early season sidedress)	125
15,16	LCD every other row application	Spring (early season sidedress)	125
17	Kura clover	-	no fertilizer
18	Orchardgrass + Red/Ladino clover	-	no fertilizer

* within the corn and soybean rotation treatments, even numbers are soybean and receive no nitrogen.

The treatments included allow for varied comparisons as follows:

- Timing of nitrogen application (treatments 1,2 and 3,4 vs. 5,6 and 7,8)
- Rate of nitrogen application (treatments 1,2 vs. 3,4 and 5,6 vs. 7,8 vs. 9,10)
- Method of nitrogen application (treatments 7,8 vs. 15,16)
- Potential impacts of tillage (treatments 7,8 vs. 11,12)
- Cropping practices through the use of a winter cover crop (treatments 7,8 vs. 13,14)
- Impacts of complete conversion to perennial vegetation (treatments 17 and 18 vs. other treatments)

These treatments allow for comparison of existing questions related to lower rates of nitrogen application and the potential impacts of fall nitrogen fertilizer application. Additionally, the LCD method of application is being investigated to determine if this application method can reduce nitrate leaching. Inclusion of the strip tillage system will investigate and demonstrate a minimal tillage system and assess its impacts on crop yield and nitrate leaching. Inclusion of cover crops and harvestable perennials allows for evaluating alternative cropping practices and the impact on nutrient movement and drainage. Evaluation of these alternatives is important for considering progressive methods for minimizing nutrient transport from tile-drained landscapes. The concentration and loading of nutrients exiting the various treatments will be monitored and evaluated on an annual basis and for the five-year study period, 2005-2009. In addition, crop yield will be documented each year to evaluate treatment effects on yield, specifically whether there are declines in annual yield at the lower nitrogen rate applications. The evaluation of the treatment effects will be for the study period but each year will be analyzed to evaluate treatment effects on a yearly basis and after the completion of this phase of the research study. It is understood that climatic variability plays a significant role in the leaching of nutrients in the tile drained landscape.

From this, it is important to have numerous years of leaching data to evaluate the treatment effects both from a production (crop yield) perspective and a nutrient leaching perspective. The multiple years of data allows for evaluating how the treatments respond under varying climatic conditions and after subsequent years with similar cropping practices. Also, these multiple years of data allow for additional characterization of tile flow under varied precipitation conditions and allow for further understanding of the hydrology of the site.

Agronomic Activities
Agronomic field activities were completed in a timely manner prior to and during the crop season. Fall chisel plowing was performed on November 2-3, 2004. Fall fertilization was completed on November 15.Tillage for seedbed preparation was completed in the spring just prior to planting of perennial crops on April 18th and followed by 0.72” of precipitation. Seedbed preparation for corn and soybean was also completed just prior to May 3 and 4 seeding dates. Fertilizer was applied just after crop emergence on May 12-13th.

Weed Control
Round Up ready crops were used at the site. Dual II was used for pre-plant weed control and was broadcast on May 10. First application of Round Up was on May 21. Second application was on June 17.Weed control was acceptable in most soybean plots; poor control of lambsquarter was noted in 6 of 32 plots, likely due to sprayer malfunction or poor herbicide application timing. Corn weed control was superior; no specific weed control problems were observed. Cultivation for weed control was not incorporated into the weed management system.

Precipitation
Precipitation was recorded at the site from April through November; freezing weather (Jan-March and December) precipitation was obtained from NOAA weather stations in Pocahontas and Humboldt (Table 2). January through March precipitation was slightly below normal at the site. April, May and June were each above normal (0.4” to 1.15” higher). July precipitation was nearly 2”, August nearly 3” and September 1.4” below normal. Highest individual storm event precipitation was on June 25-26 when 2.65” were recorded.

Table 2. Precipitation in 2005 at the research site and comparisons to norms and amounts at local NOAA weather stations.

Precipitation at the ADW site in 2005				NOAA weather stations in 2005		
			normal*	Pocahontas	Humboldt	average
	mm	inches	inches		inches	
Jan	-	-	0.91	0.62	0.60	0.61
Feb	-	-	0.70	1.77	1.60	1.69
Mar	-	-	2.20	1.33	1.07	1.20
Apr	89	3.49	3.09	3.32	3.61	3.47
May	129	5.09	3.94	5.85	4.15	5.00
Jun	134	5.27	4.37	7.46	8.89	8.18
Jul	63	2.47	4.37	3.82	4.42	4.12
Aug	45	1.76	4.60	1.41	3.20	2.31
Sep	39	1.53	3.16	3.38	4.54	3.96
Oct	20	0.79	2.17	1.00	0.59	0.80
Nov	43	1.69	1.86	1.50	2.18	1.84
Dec	-	-	1.37	N/A	N/A	N/A
total			32.74	31.46	34.85	33.16

N/A: not available at time of report preparation, totals are for months with values.

Drainage

Average soil temperature at a 4” depth rose above freezing on March 22 and continued to rise. Treatment plot sampling pumps were installed during the last week of March. Drainage started during this period and the first samples were collected on April 1st. Eighteen of the seventy-two plots had enough drainage to provide a sample on this date. By the 7th, fourteen additional plots were sampled. Samples were collected on at least a weekly basis, and for most plots, drainage was sufficient for sampling through the month of June. Only ten plots had drainage in July; the last samples were gathered on July 26th. Table 3 lists drainage volumes by treatment in 2005 with statistical differences at p=0.05. Five of the eighteen treatments had one of four replications removed due to excessive drainage volume values. Statistical differences among treatments were noted for four of eighteen treatments (LSD=7.22 inches). Average drainage for all treatments was 8.45 inches. When the treatments were grouped by crop (C vs. S) it was noted that there was a significant difference between crops, with soybean having a lower value (C=10.17”, S=7.19”) possibly related to tillage operations performed prior to the drainage season. With 23.29” of precipitation between March 1 and November 30 and using an overall drainage volume of 8.45”, approximately 36% of the precipitation became subsurface drainage. Nearly half of the precipitation amount that occurred between March and the end of July, when drainage ceased, became subsurface drainage (see Table 4). The site was winterized on December 5.

Table 3. Subsurface drainage volumes with statistical differences at p=0.05, by treatment in 2005.

Treatment	Description	Drainage (inches)
1	Fall 75 Corn	12.03a
2	Fall 75 soybean	7.14ab
3	Fall 125 Corn	11.07ab
4	Fall 125 soybean*	7.31ab
5	Spring 75 Corn	11.72ab
6	Spring 75 soybean	5.27ab
7	Spring 125 Corn*	4.70b
8	Spring 125 soybean	5.95ab
9	Spring 150 Corn	12.49a
10	Spring 150 soybean	7.55ab
11	Strip 125 Corn*	9.70ab
12	Strip 125 soybean*	4.80b
13	Cover Crop 125 Corn*	6.98ab
14	Cover Crop 125 soybean	10.53ab
15	LCD 125 Corn	9.65ab
16	LCD 125 soybean	6.78ab
17	Kura clover	10.08ab
18	Orchardgrass + Red/Ladino clover	8.29ab
LSD		7.22
average drainage		8.45
standard deviation		2.53
average for corn treatments		10.17
average for soybean treatments		7.19**

* one of four reps not included in this average because of an excessive drainage value.
** significantly different from drainage for corn treatments at p=0.05

Table 4. Average drainage for each month over all treatments with totals and percentage as drainage for April- July 2005.

month	precipitation	drainage	percentage
	------inches------		
April	3.49	2.82	81
May	5.09	3.23	63
June	5.27	2.46	47
July	2.47	0.12	5
total	16.32	8.63	53

Nitrate Concentrations and Losses

Previous history of current plot treatments quite likely has influenced the nitrate-nitrogen concentrations observed during 2005. The majority of plots received 150 lbs N/acre during the period of 2000-2004 either as manure or aqua ammonia in the spring or fall. The previous experimental phase also included a split plot methodology with both corn and soybean grown on each plot, as opposed to the current phase utilizing whole plots, which has also contributed to and confounded this year's results. No definitive treatment effect trends should be derived from this 'calibration' year's concentration results. In 2005, 535 flow weighted water samples were gathered. Table 5 lists the treatment results. Only the highest and three lowest average concentrations, out of eighteen compared, exhibited significant differences at p=0.05 level. The highest NO_3-N average concentration (18.8 mg/L NO_3-N) was observed in a treatment that was in the soybean year of the rotation and received no nitrogen in 2005. In the previous phase, two of the four replications for this treatment received 225 lbs N/acre and is quite likely a major factor in the elevated levels of NO_3-N observed. Lowest concentration observed was for two treatments: strip tillage 125 and LCD 125 cropped to corn, both averaged 12.9 mg/L NO_3-N.

Table 5. Nitrate concentrations by treatment in 2005 with statistical significance at p=0.05.

Treatment	Description	nitrate N (mg/L) p=0.05
1	Fall 75 Corn	14.5ab
2	Fall 75 soybean	17.8ab
3	Fall 125 Corn	14.5ab
4	Fall 125 soybean	13.5ab
5	Spring 75 Corn	13.5ab
6	Spring 75 soybean	18.8a
7	Spring 125 Corn	18.1ab
8	Spring 125 soybean	17.0ab
9	Spring 150 Corn	16.3ab
10	Spring 150 soybean	15.8ab
11	Strip 125 Corn	12.9b
12	Strip 125 soybean	14.2ab
13	Cover Crop 125 Corn	13.9ab
14	Cover Crop 125 soybean	14.4ab
15	LCD 125 Corn	12.9b
16	LCD 125 soybean	16.1ab
17	Kura clover	13.1b
18	Orchardgrass + Red/Ladino clover	14.7ab
	LSD	5.4

Table 6 lists NO_3-N losses by treatment in 2005. Losses were calculated by multiplying subsurface drainage effluent concentration by drainage volume. Due to the inherent variability between experimental plots and among treatments loss calculations for one year may not be the best indicator of treatment effect. Losses ranged from 17.4 lbs NO_3-

N for soybean grown under a strip tillage system, with no fertilizer added in 2005 to 41.1 lbs NO_3-N exiting the subsurface drainage system for an early season sidedress application of 150 lbs N/acre on corn. (Fertilizer was applied on May 12-13.) These two treatments were the only statistically different (p=0.05) treatments for loss.

Table 6. Nitrate losses by treatment in 2005 with statistical significance at p=0.05.

Treatment	Description	nitrate-N (lbs/acre)
1	Fall 75 Corn	38.4ab
2	Fall 75 soybean	23.9ab
3	Fall 125 Corn	35.4ab
4	Fall 125 soybean	23.7ab
5	Spring 75 Corn	35.3ab
6	Spring 75 soybean	23.6ab
7	Spring 125 Corn	21.8ab
8	Spring 125 soybean	23.7ab
9	Spring 150 Corn	41.1a
10	Spring 150 soybean	27.7ab
11	Strip 125 Corn	27.8ab
12	Strip 125 soybean	17.4b
13	Cover Crop 125 Corn	20.0ab
14	Cover Crop 125 soybean	34.9ab
15	LCD 125 Corn	29.7ab
16	LCD 125 soybean	24.5ab
17	Kura clover	26.3ab
18	Orchardgrass + Red/Ladino clover	26.1ab
	LSD	22.9

Late Spring Nitrate Test

Each corn plot was sampled using the Late Spring Nitrate Test (LSNT) procedures for determination of nitrate-nitrogen concentrations in the top 12” of soil on June 17, when corn plants were approximately 10” tall. Table 7 lists soil test results and the additional application amount recommended. Test results were for information only and no additional N applications were made. Fall N application plots had lower test values than plots with N applied in the spring. The spring 150 (treatment 9) plots had the highest N concentrations and the fall 125 (treatment 3) the lowest.

Stalk Nitrate Test

Corn stalk nitrate test sampling protocols were followed to determine nitrate-N concentrations in corn stalk tissue from each plot. Results are listed in Table 8. Stalks were sampled on September 29. Stalk nitrate values can be divided into four categories: low (less than 250 mg/L-N) marginal (250-700) optimal (700 and 2000 mg/L-N). Only the spring 150 treatment was in the optimal range, all other treatments were in the marginal to low range.

Table 7. Late Spring Nitrate Test (LSNT) nitrate-N concentrations and additional N recommended but not applied in 2005.

Treatment	Description	nitrate-N (mg/L)	additional N (lb/acre)
1	Fall 75 Corn	8	136
3	Fall 125 Corn	6	150
5	Spring 75 Corn	10	122
7	Spring 125 Corn	9	132
9	Spring 150 Corn	18	54
11	Strip 125 Corn	10	122
13	Cover Crop 125 Corn	10	122
15	LCD 125 Corn	16	72

Table 8. Stalk nitrate test concentrations in 2005. Optimal range is between 700 and 2000 mg/L-N.

Treatment	Description	nitrate-N* (mg/L)
1	Fall 75 Corn	32
3	Fall 125 Corn	67
5	Spring 75 Corn	83
7	Spring 125 Corn	186
9	Spring 150 Corn	1032
11	Strip 125 Corn	260
13	Cover Crop 125 Corn	178
15	LCD 125 Corn	178

* low (less than 250 mg/L-N) marginal (250-700) optimal (700-2000 mg/L-N).

Yields

Corn and soybean yields, by treatment, are listed in Tables 9 and 10. Because of the plot configuration in 2004, when corn and soybean were both grown on the same plot, yields for 2005 could be separated into those that followed the same crop or were grown in rotation. Continuous corn yield depression ranged from 12-31%, with an average 18%. Soybean on soybean yield depression was 6-11%, with an average of 9%. Considering only the crops in rotation, yields ranged from 156-179 bu/acre; lowest yield was for Fall 75 treatment and highest for Spring 150. The comparison resulted in a significant difference at $p=0.05$. All other treatments were not statistically different from these two values. Soybean yield in rotation ranged from 48-53 bu/acre and no significant differences were noted.

Table 9. Corn yield by treatment in 2005 with statistical significance at p=0.05*.

Treatment	Description	yield (bu/acre) p=0.05 continuous	rotation
1	Fall 75 Corn	108d	156b
3	Fall 125 Corn	137abc	164ab
5	Spring 75 Corn	134bc	162ab
7	Spring 125 Corn	153ab	173ab
9	Spring 150 Corn	156a	179a
11	Strip 125 Corn	152ab	174ab
13	Cover Crop 125 Corn	134bc	163ab
15	LCD 125 Corn	125cd	163ab
Pocahontas County average – 183 bu/acre			

*significance within a system, i.e. within the rotation.

Table 10. Soybean yield by treatment in 2005 with statistical significance at p=0.05*.

Treatment	Description	yield (bu/acre) p=0.05 continuous	rotation
2	Fall 75 Soybean	47a	50a
4	Fall 125 Soybean	44a	48a
6	Spring 75 Soybean	46a	51a
8	Spring 125 Soybean	44a	49a
10	Spring 150 Soybean	47a	53a
12	Strip 125 Soybean	45a	50a
14	Cover Crop 125 Soybean	49a	53a
16	LCD 125 Soybean	46a	49a
Pocahontas County average – 50 bu/acre			

*significance within a system, i.e. within the rotation.

Summary

Crop year 2005 could be considered a ‘calibration’ year for the new treatments imposed at the research site. So, it is difficult to draw broad conclusions from crop year 2005. However, of note is that in the 1st year of conversion from a row-crop system to a perennial system we have seen little if any reduction in nitrate-N concentration. Another important observation is that during April 2005 approximately 81% of the precipitation was intercepted by and exited via the subsurface drainage system. During crop year 2006 we expect to begin to see treatment effects as the carryover from previous treatments prior to this phase should be reduced.

Pekin Project Site

Drainage management practices are being evaluated at the Pekin school drainage facility. There are a total of nine plots at this facility. Three different management practices are being be utilized and evaluated. The treatments include the following:

- 3 – plots with conventional drainage (Free flow (FF)).
- 3 – plots with controlled drainage with free flow in the spring (April –May) and fall (September-October) (Controlled drainage variable (CDV)). The outlet control will be set at 2 ft below the ground surface except during free flow.

- 3 – plots with controlled drainage with no free flow (Controlled drainage fixed (CDF)). This treatment would be used to represent a system similar to shallow drainage. The outlet control will be set at 2 ft below the ground surface.

These three treatments are being evaluated to investigate the impacts of drainage management practices on drainage volume, nutrient concentrations in the subsurface drainage, and grain yield. Again, these factors will be evaluated over the five-year term of this project. Since significant climate variability exists and the response of variable weather conditions on drainage management systems is needed it is important to evaluate the treatment response over the entire duration of the project phase. In addition to drainage management practices, drainage from two plots flows through a passive biofilter. One of the plots is a FF plot and one is a CDF plot. The concentration of nutrients entering and exiting the biofilter is being monitored to document any reductions as a result of the passive biofilter.

Crop year 2005 was an unusually dry year at the Pekin site as the precipitation from mid-March through the end of 2005 was less than 18 inches (Figure 1) with only about 8 inches from mid-March through the end of June. There was on average slightly less than 4 inches of drain flow from the free flow plots and less than 2 inches of flow from the controlled drainage plots (Figure 1). It is likely that there is some lateral seepage from the controlled drainage plots to the free flow plots. This factor will be evaluated in greater detail in 2006 in an attempt to quantify the amount of lateral flow to draw a more complete picture of the impact of controlled drainage. The nutrient data and crop yield from this site are still being evaluated.

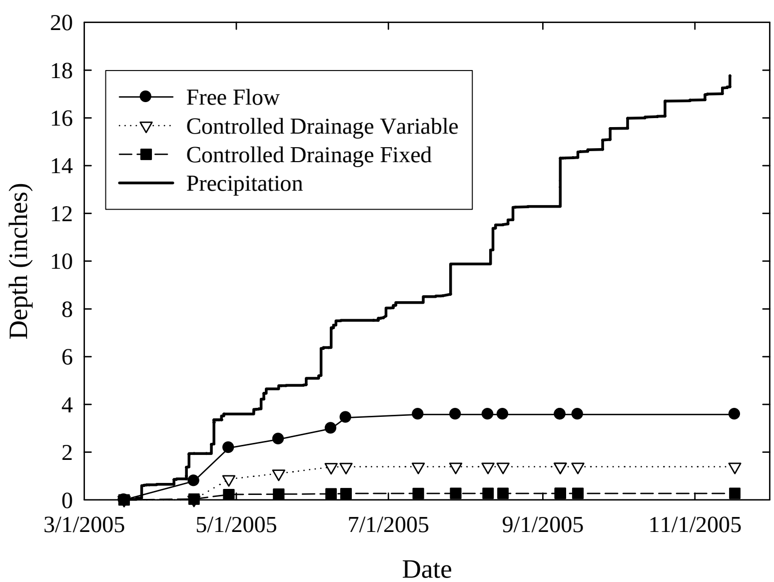

Figure 1. Precipitation and subsurface drainage at the Pekin site in 2005.

Wetlands Monitoring and Evaluation

A unique aspect of the Iowa CREP is that nitrate reduction will not simply be assumed based on wetland acres enrolled, but will be calculated based on the measured performance of CREP wetlands. As an integral part of the Iowa CREP, a representative subset of wetlands will be monitored and mass balance analyses will be performed to document nitrate reduction. This will allow further refinement of modeling and analysis tools used to site and design CREP wetlands.

During all or part of the 2003 through 2005 crop seasons, eight different wetlands have been monitored for the Iowa CREP. These include RF Wetland, DH Wetland, AL Wetland, lower ML Wetland, upper ML Wetland, KS Wetland, TI Wetland, and VH Wetland. For close interval monitoring of nitrate-nitrogen concentrations, wetlands were instrumented with automated samplers that collected daily composite water samples at wetland inflows and outflows. Grab samples were collected at an approximately weekly interval at the inflow and outflow, and from within the wetland near the outflow location when there was no outflow. For these wetlands, the automated sampler also measured water depth and flow velocity during part of the season. A cross-section profile was measured at the autosampler depth and velocity probe deployment location and a depth versus cross-sectional area relationship was developed. This was used with the water depth and velocity measurements to generate a daily discharge. To estimate flow at sites or during periods for which autosampler depth and velocity data were not collected, flow rates were obtained from flow data of nearby USGS river gauging stations adjusted to represent the drainage area of the wetland.

By design, the wetlands selected for monitoring span the wetland/watershed area ratio range of 0.5% - 2.0% approved for Iowa CREP wetlands. The wetlands also span a range of average nitrate nitrogen concentrations from approximately 8 to 30 mg/l. The wetlands thus provide a broad spectrum of those factors most affecting wetland performance: hydraulic loading rate, residence time, nitrate concentration, and nitrate loading rate. Despite significant variation with respect to average nitrate concentrations and loading rates, the wetlands display similar seasonal patterns. Nitrate concentrations and mass loads are highest during high flow periods in spring and early summer, and decline with declining flow in late summer and fall. These nitrate concentration and flow patterns are representative of the patterns that are expected for future wetlands restored as part of the Iowa CREP.

Nitrate Loss from Wetlands

Over the 2003-2005 monitoring periods, the wetlands have performed predictably with respect to nitrate removal efficiency (expressed as percent removal) and mass nitrate removal. Wetland performance is a function of hydraulic loading rate, nitrate concentration, temperature, and wetland condition. Of these, hydraulic loading rate and nitrate concentration are the most important. Hydraulic loading rate is in part determined by wetland/watershed area ratio and the 0.05 to 2 percent wetland/watershed area ratio range approved for Iowa CREP wetlands can be expected to result in a four-fold range in hydraulic loading rate. However, the actual range in hydraulic loading rates is significantly greater due to spatial and temporal patterns in precipitation. In addition to spatial variation in precipitation (average precipitation declines from southeast to northwest across Iowa), there is tremendous year to year variation in precipitation. This can contribute an additional 3-5 fold variation in hydraulic loading rate over a typical 10 year period. Hydraulic loading rates to CREP wetlands can be expected to vary by an order of magnitude, and will to a large extent determine nitrate loss rates for individual wetlands.

Mass balance modeling was used to examine the long term performance expected for 7 operating wetlands and wetlands that will be constructed in 2006. For existing wetlands, close interval monitoring in 2003, 2004, and 2005 provided estimates of flow weighted nitrate concentrations at wetland inflows. For wetlands to be constructed in 2006, grab samples during spring high flow periods were used to estimate flow weighted nitrate concentrations at wetland inflows. Mass balance modeling was used to hindcast annual nitrate loads and nitrate removal for each of these wetlands over the 10 year period from 1996 through 2005. Recognizing that none of the CREP wetlands have been in place for more than a few years, this analysis is intended only to illustrate the expected performance over a representative 10 year period, if the wetlands had been constructed prior to the beginning of that period. Figure 2 illustrates the 10 year average mass loading and loss for individual wetlands at specific locations within the CREP service area.

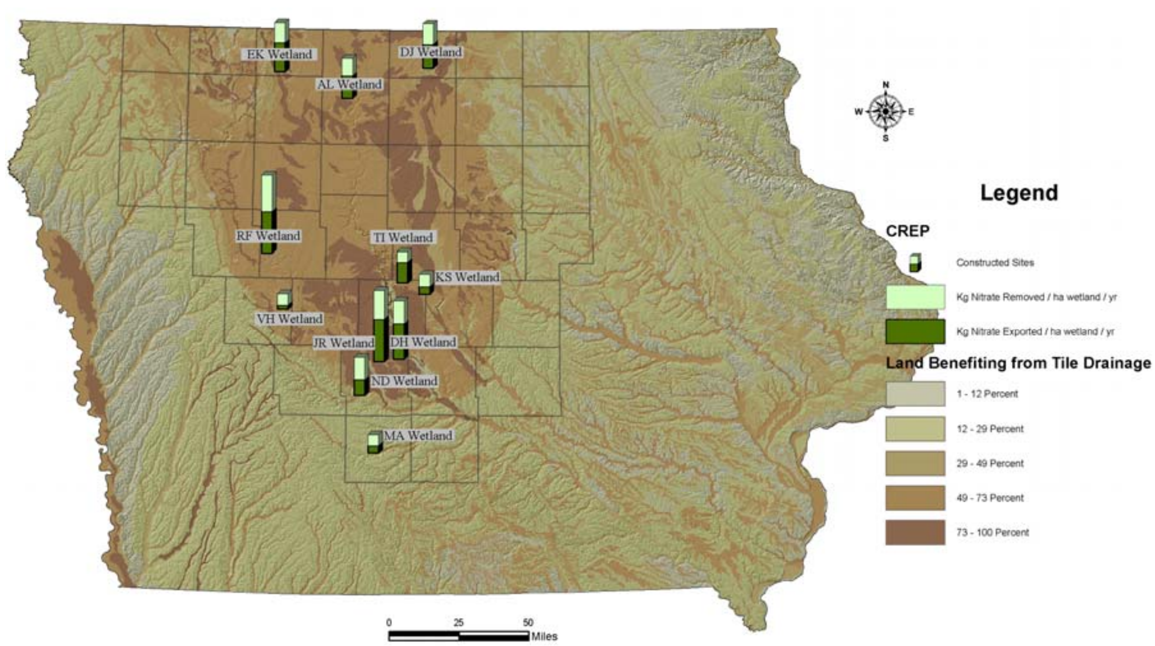

Figure 2. Predicted ten year average nitrate-N loading and loss rates (normalized to wetland area) for selected wetlands in the Iowa CREP service area for 1996 to 2005 input conditions.

Figure 3 illustrates the results predicted for six of the existing wetlands including flow rates entering each wetland, annual mass nitrate loading to each wetland, annual mass nitrate removal by each wetland, and annual % nitrate removal by each wetland. Widely varying annual loading and loss rates can be expected for any given wetland driven largely by yearly differences in precipitation and flow volumes. The wetlands can simply be expected to receive and remove much greater masses of nitrate in wet years than in dry year

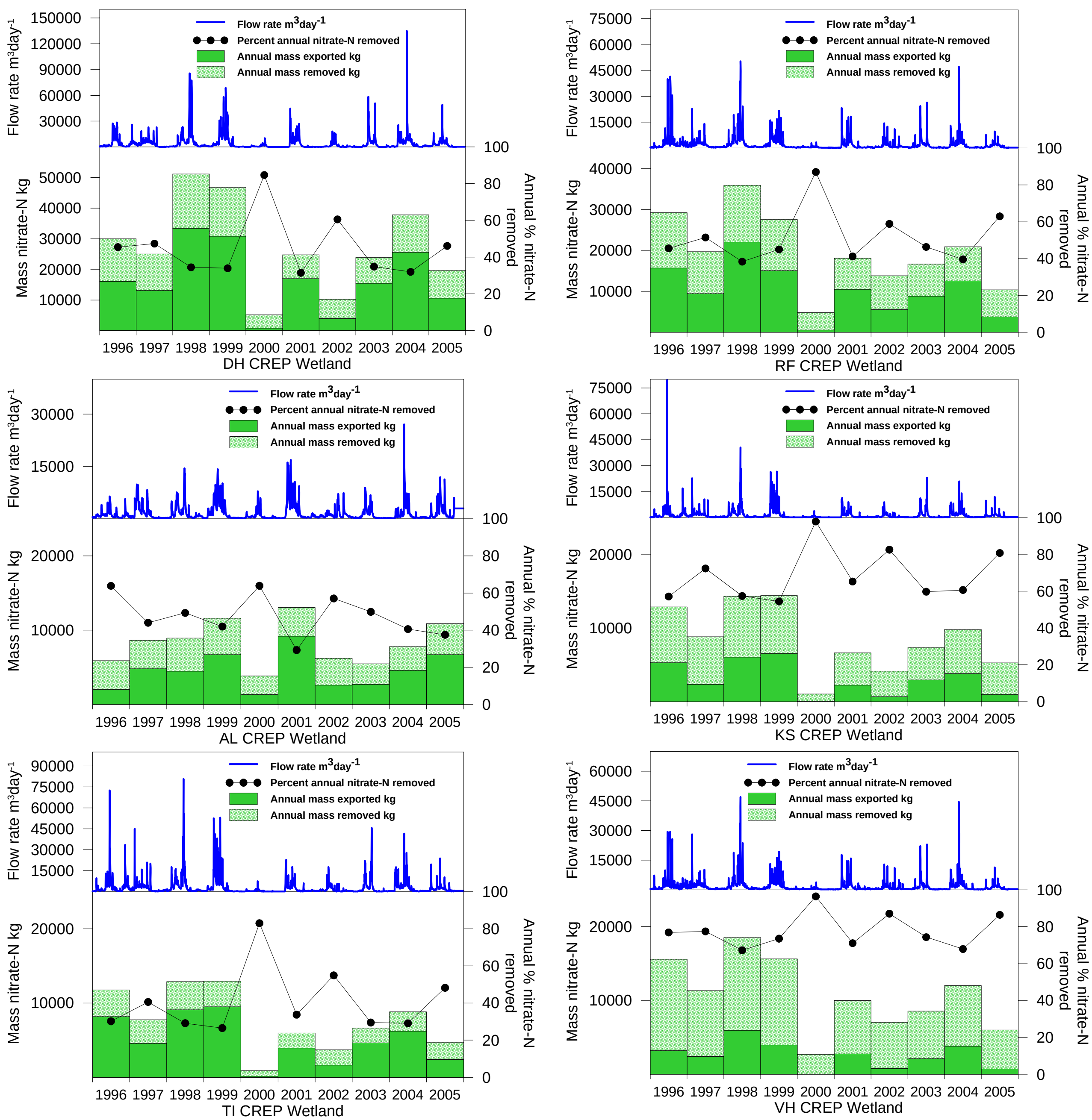

Figure 3. Predicted annual nitrate-N loading and loss rates for selected wetlands in the Iowa CREP service area for 1996 to 2005 input conditions.

Figure 4 illustrates the percent nitrate removal expected for the wetlands over the 10 year hindcast period. For comparison, percent nitrate removals measured for VH Wetland and RF Wetland in 2004 are also presented in Figure 4, and illustrate reasonably good correspondence between observed and modeled performance of the wetlands. As could be expected, the predicted percent nitrate removal is clearly a function of hydraulic loading rate.

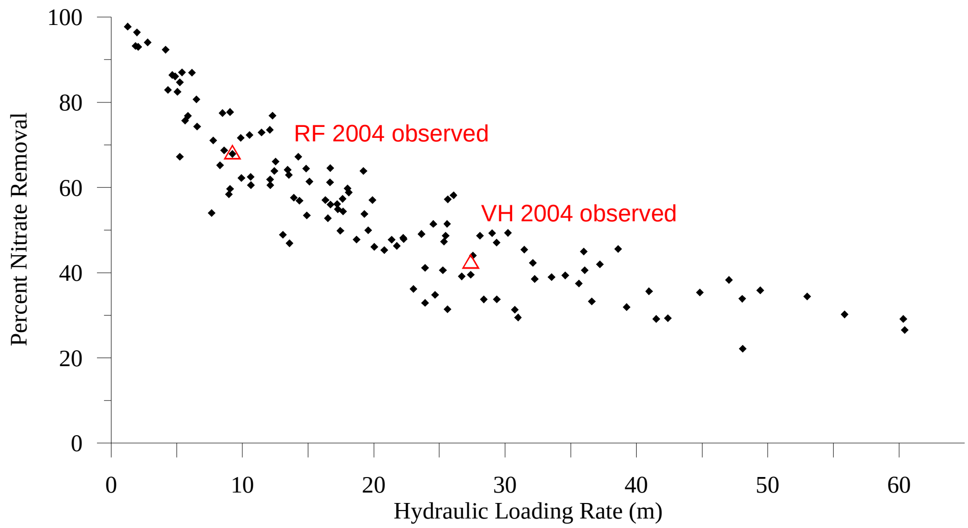

Figure 4. Modeled percent nitrate removal for 1996 to 2005 input conditions.

In contrast to percent removal, mass removal is not determined primarily by hydraulic loading rate. Although mass removal is constrained at lower hydraulic loading rates, mass removal rates vary widely at higher hydraulic loading rates (Figure 5). By itself, hydraulic loading rate explains relatively little of the pattern in nitrate mass removal rates. The observed mass removal rates are predictable using dynamic mass balance models integrating hydraulic loading rates, nitrate concentration, and temperature.

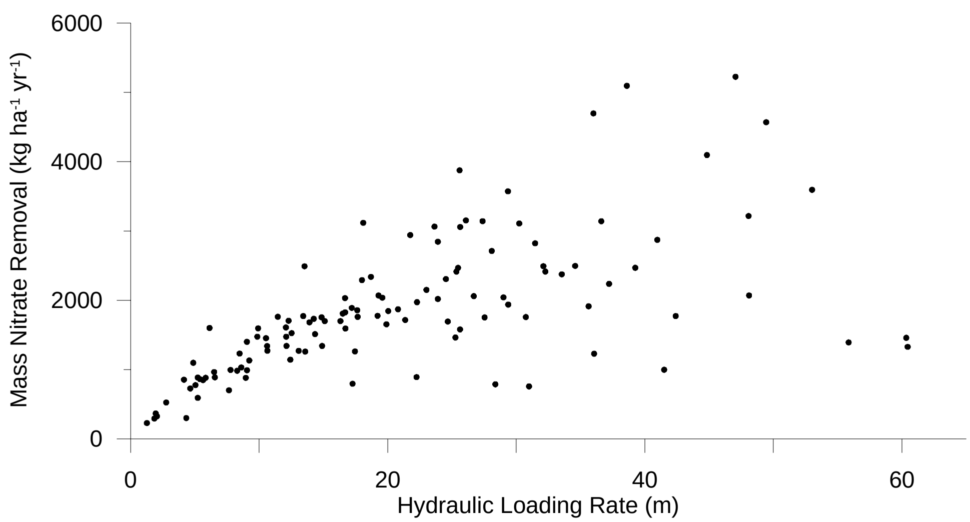

Figure 5. Modeled mass nitrate removal for 1996 to 2005 input conditions.

Nitrate in Tile Drained Watersheds: Synoptic Sampling Program

As discussed above, hydraulic loading rates are expected to vary significantly as a result of wetland/watershed ratios and precipitation patterns even for identical watersheds. However, nitrate concentrations are thought to be primarily determined by agricultural practices and drainage patterns, and are expected to be similar for tile drained watersheds in the same geographic area and with similar agricultural practices. However, monitoring of CREP wetland inflows demonstrated a greater than three-fold range in average nitrate concentrations, with no clear relationship to agricultural practices or drainage patterns. It is possible that differences in nitrate concentration are related to underlying landscape characteristics and that if these could be identified and understood, CREP wetlands could be targeted even more effectively.

Over the past two field seasons, we have implemented a broader monitoring program in an effort to better understand and predict the variation in nitrate concentration from tile drained watersheds in the CREP service area. During the 2004 and 2005 growing seasons, samples were collected from tile drained watersheds at approximately weekly intervals and analyzed for nitrate. In 2004, 46 sites were sampled in four Iowa counties. In 2005, sampling was continued at 23 sites in Cerro Gordo and Franklin Counties chosen to cover the range of concentrations found in the original 46 sites.

Water flow was estimated from nearby USGS gauging station discharge data adjusted to the estimated watershed area for each tile to allow a matching of temporal variation of nitrate concentrations with flow events and to allow estimation of flow-weighted average (FWA) nitrate concentrations. Because the actual flow is not known, field notes describing flow at the time of sampling were useful in interpreting low nitrate values that were occasionally observed when the flow was either zero or very low, even though the nearby gauging station indicated flow might be occurring. Nitrate concentrations in 2004 were generally similar to or somewhat greater than the 2005 values and nitrate concentrations at each location remained relatively consistent between years. The flow-weighted average nitrate concentrations show an approximate three-fold range at these sites (Figure 6).

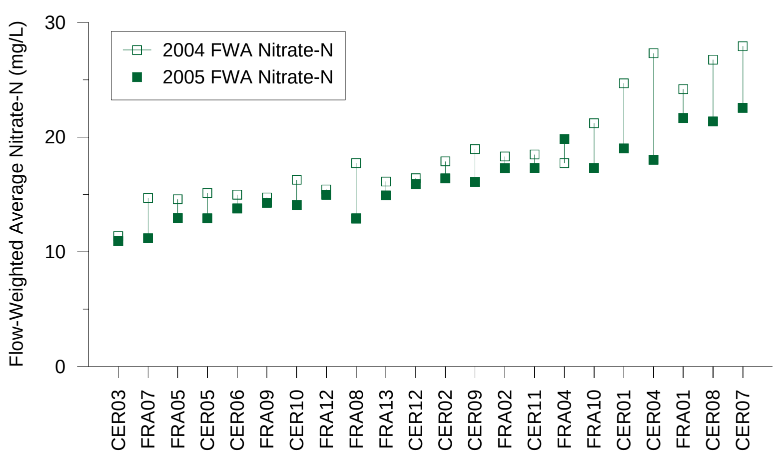

Figure 6. FWA nitrate-N for 2004 and 2005 at synoptic tile sampling sites.

We are currently exploring relationships between nitrate concentration and underlying landscape characteristics in an effort to understand and eventually predict variability in nitrate concentrations in tile drained watersheds with similar agricultural practices. The nitrate concentrations for each site were compared with watershed characteristic summarized from available soil survey attributes, surface slope, and Landsat land-use classification. Watershed boundaries were delineated using the USGS 30m Digital Elevation Model (DEM) and a simple D8 flow direction algorithm. Watershed characteristics were average values from a 30m grid generated for a specific attribute. Soil survey attribute grids were derived from ISPAID datasets which had compiled county soil survey information to a GIS database form. The county by county basis of this information produces some variability of a soils attribute between counties. However, the values reported do represent a relative scale of attribute values. All attributes in the ISPAID database that could reasonably have an effect on water flow or nitrate concentration were evaluated for statistical significance. Surface slope was derived from the DEM. The Landsat land-use was only analyzed for the 5 major land-use classifications found in the study area. It is generally known that nitrate concentrations are positively correlated with %RC. However, by design, the range of %RC across these study sites is low (about 84 to 98%) and thus explains very little of the variability in nitrate concentration. We have yet to identify any strong relationships between nitrate concentration and the landscape characteristics examined. If these can be identified and understood, it might be possible to develop siting criteria such that CREP wetlands could be targeted even more effectively.

Outreach Activities

In addition to the evaluation that is taking place at the project sites, we have an active outreach program associated with this project. This includes presentations at technical and Extension related meetings, field days, the Drainage Research Forum, and Extension and scientific publications. The activities that are directly associated with the outreach component of this project are described below.

Oral Presentations at Extension Related Meetings

January 4, 2005 – Presentation “New tiling research in Iowa and economic considerations” at Crop Advantage Series meeting in Mt. Pleasant, Iowa (25 attendees).

January 6, 2005 – Presentation “New tiling research in Iowa” at Crop Advantage Series meeting in Cedar Rapids, Iowa (40 attendees).

January 11, 2005 – Presentation “Tiling research at Iowa State University” at Iowa Land Improvement Contractors of America annual meeting in Des Moines, IA (60 attendees).

January 12, 2005 – Presentation “Modified drainage for improved water quality” at North Central Crop Clinic in Iowa Falls, IA (45 attendees)

January 25, 2005 – Presentation “New tiling research in Iowa” at Crop Advantage Series meeting in Atlantic, Iowa (120 attendees).

January 26-27, 2005 – Presentation “Drainage design and management” at Heartland Water Quality Initiative Nitrogen Roundtable in Nebraska City, NE (30 attendees from Iowa, Nebraska, Kansas, Missouri, and USEPA).

March 1-3, 2005 – Presentation “Wetland design for drainage water treatment” at Minnesota Agricultural Drainage Design Workshop in Mankato, MN (45 attendees).

June 7-9, 2005 – Presentation “Subsurface drainage and treatment of drainage water to reduce nitrate-N” at Heartland Water Quality Initiative Nitrogen Workshop in Nebraska City, NE (75 attendees from Iowa, Nebraska, Kansas, Missouri, and USEPA).

June 7-9, 2005 – Presentation “Design of drainage water treatment facilities” at Heartland Water Quality Initiative Nitrogen Workshop in Nebraska City, NE (20 attendees from Iowa, Nebraska, Kansas, Missouri, and USEPA).

July 7, 2005 – Presentation “Drainage design for crop production and environmental benefits” at Pro Ag Meeting, Mitchell County Extension, Osage, IA (15 attendees).

July 28, 2005 – Presentation “Subsurface drainage design and drainage water management in Iowa” at Ag Insights: Water Management Solutions, meeting sponsored by Hancor in Oelwein, IA (50 attendees).

August 24, 2005 – Presentation “Manure effects of water quality” at Manure Management Clinic in Ames, IA (40 attendees).

November 30 and December 1, 2005 – Presentation “Conservation systems: effects of manure on drainage water quality” at Integrated Crop Management conference in Ames, IA (220 attendees).

December 15, 2005 – Presentation “Drainage management and cropping practices” at Iowa Drainage District Association annual meeting in Fort Dodge, IA (75 attendees).

Poster Presentations at Extension Related Meetings

Helmers, M. J., P. A. Lawlor, J. L. Baker, S. W. Melvin, W. Crumpton, D. W. Lemke. 2005. Temporal subsurface flow patterns from fifteen years in north-central Iowa. Agriculture and the Environment Conference (March 8-9, 2005, Iowa State University, Ames, IA).

P. A. Lawlor, M. J. Helmers, J. L. Baker, S. W. Melvin, W. Crumpton, D. W. Lemke. 2005. Nitrogen application rate effects on yield, nitrate-nitrogen concentration and loss in subsurface drainage. Agriculture and the Environment Conference (March 8-9, 2005, Iowa State University, Ames, IA).

Extension Related Publications

Helmers, M. J. and P. A. Lawlor. 2005. Conservation systems: Effects of manure application on drainage water quality. In *Proceedings of the 17th Annual*

Integrated Crop Management Conference (November 30 and December 1, 2005, Iowa State University, Ames, IA), pp. 177-188.

Technical Papers and Oral Presentations

Lawlor, P. A., M. J. Helmers, J. L. Baker, S. W. Melvin, and D. W. Lemke. 2005. Nitrogen application rate effects on corn yield and nitrate-nitrogen concentration and loss in subsurface drainage. ASAE Meeting Paper No. 05-2025. St. Joseph, MI: ASAE.

M. J. Helmers, P. A. Lawlor, J. L. Baker, S. W. Melvin, and D. W. Lemke. 2005. Temporal subsurface flow patterns from fifteen years in north-central Iowa. ASAE Meeting Paper No. 05-2234. St. Joseph, MI: ASAE.

Field Days

A field day was organized at the Gilmore City project site (Figures 7 and 8). The evening field day on June 30, 2005 was attended by approximately 75 stakeholders. The topics discussed were current crop issues (Paul Kassel), nitrate-removal wetlands (Dr. William Crumpton), the Targeted Watershed Grant (Dean Lemke and County Board of Supervisors), highlights from 15 years at Gilmore City (Dr. Stewart Melvin, Peter Lawlor, and Dr. James Baker), and controlled drainage (Matt Helmers).

Carl Pederson and Matt Helmers presented on drainage water quality and drainage water management at a field day at the Pekin project site on September 15, 2005. The “8 to 80 Water Quality Field Day” was attended by approximately 100 students from surrounding schools.

Drainage Research Forum

The 6th Annual IA-MN Drainage Research Forum was held on November 2, 2005 in Dows, IA. The forum was attended by 80 stakeholders that included individuals from both Iowa and Minnesota.

The program focused on drainage and water management issues including the implications of nitrogen management, water quality and drainage modeling at the watershed scale, preferential flow on drained lands, nitrate-removal wetlands, cropping strategies for nitrogen management and drainage water management. Presenters included researchers from Iowa State University, University of Minnesota, and the USDA Agricultural Research Service.

Planned Outreach Activities

Presentations at various Extension, technical, and general audience venues will continue to broaden the impact from this study.

A general summary report for the Gilmore City project through 2004 is being prepared and is expected to be released in 2006. At present the report is being edited.

Technical publications that examine the effects of nitrogen application rate and timing on nitrate leaching are being prepared. At present they are going through internal review by co-authors.

Since the Pekin project site is one of the drainage water management sites in Iowa, a site tour of interested stakeholders will be planned for 2006.

Figure 7. Field day at Gilmore City project site held June 30, 2005

Figure 8. Field day at Gilmore City project site held June 30, 2005